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Analysis Methods for Small-Scale Surface Network Data

by

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ANALYSIS METHODS FOR SMALL-SCALE SURFACE NETWORK DATA

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ABSTRACT

Methods of data reduction and techniques of analysis are presented with respect to small-scale surface network data. Examples have been taken from case studies, using data of the NSSP Beta network. Procedures are described for determining malfunctions of instruments, corrections for time errors, and corrections for the malalignment of charts. A method is described by which barogram readings are reduced to a sea level representation. Methods for determining empirical corrections for other types of data are shown. The concept of change lines is described and the isochrone-amplitude analysis is presented to show the intensity, extent, and motion of change lines. The construction of synoptic analyses is shown.

I. INTRODUCTION

The National Severe Storms Project operates a small-scale network of surface observational stations in south-central Oklahoma. Stations are spaced in oblique checkerboard fashion at 10- to 15-mi. intervals in a 6 by 6 array for a total of 36 stations.[1] The network extends south-southwestward from just south of Oklahoma City, Okla., to just north of Wichita Falls, Tex. Observations of surface pressure, temperature, relative humidity, wind direction, wind speed, and rainfall are continuously recorded in graphic form. A detailed index and description of the network, which is identified as the Beta network, has been prepared by Fujita [1].

Certain methods of reducing and analyzing the Beta network data have evolved at NSSP Headquarters, Kansas City, Mo. Some of these follow the excellent methods described by Fujita, Newstein, and Tepper [2], but some variations and changes have been employed. Since a number of studies are in progress and planned, it is considered appropriate that a detailed description of the methods be presented. The issuance of this report will eliminate the need for tedious descriptions of the methods in papers that follow, and it is hoped also that it may serve as a guide to others who are engaged in studies of small-scale surface data.

Examples are presented that illustrate the methods used. These have been selected from studies in progress or completed. Although Beta network data have been used, data from the Alpha network [1] or from any similar small-scale network can be treated in the same way.

[1] 1961 and 1962 network. In 1963 the network was increased to 41 stations.

2. THE DATA

The data are recorded continuously in graphic form. They consist of station pressure, temperature, relative humidity, wind direction, wind speed, and rainfall.

Station pressure is recorded by a microbarograph. Temperature and relative humidity are recorded by a hygrothermograph. The chart drums of these instruments are geared to make one revolution in 12 hours. The charts are changed once daily, so charts typically bear two sets of traces. Sample microbarogram, thermogram, and hygrogram traces for 0130-0530 CST, May 4, 1961, are shown in figure 1. The original records contained two sets of traces, but only one set is shown in the figure. One may note that a pressure fall, a temperature rise, and a humidity fall occurred in association with each other.

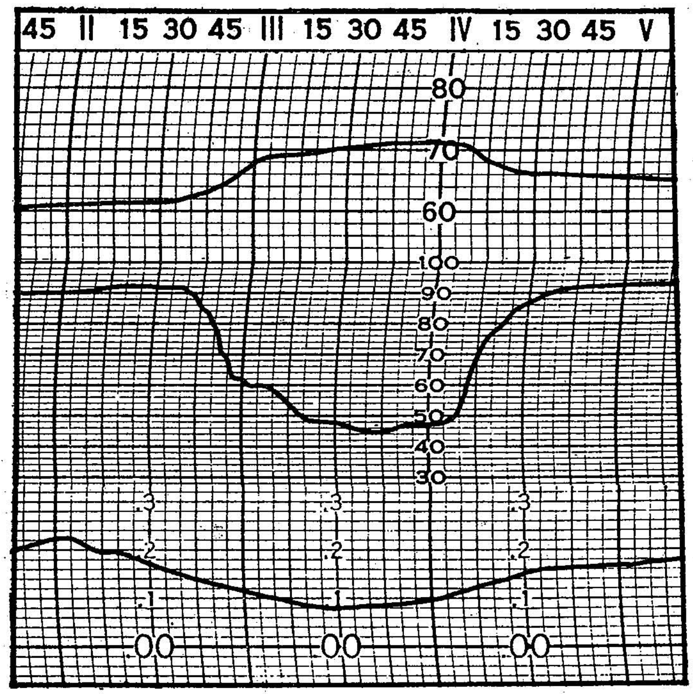


Figure 1.- Thermogram, hygrogram, and microbarogram traces for station 22, 0200-0500 CST, May 4, 1961.

Wind direction and wind speed are recorded on a chart roll. Wind direction is recorded at 1-minute intervals with respect to eight channels. Two adjacent channels may record at the same time so that the wind direction is given to 16 points of the compass. Wind speed is recorded continuously. A sample wind recorder chart for 2100-2200 CST, June 7, 1962, is shown in figure 2. One may note that a gust began at 2130 CST and that its peak of 74 kt. was attained about $2\frac{1}{2}$ mins. later. During this time the direction shifted clockwise from east-southeast to west. Direction after the shift was recorded in 3 channels, indicating that there was buffeting of the wind vane between southwest and northwest.

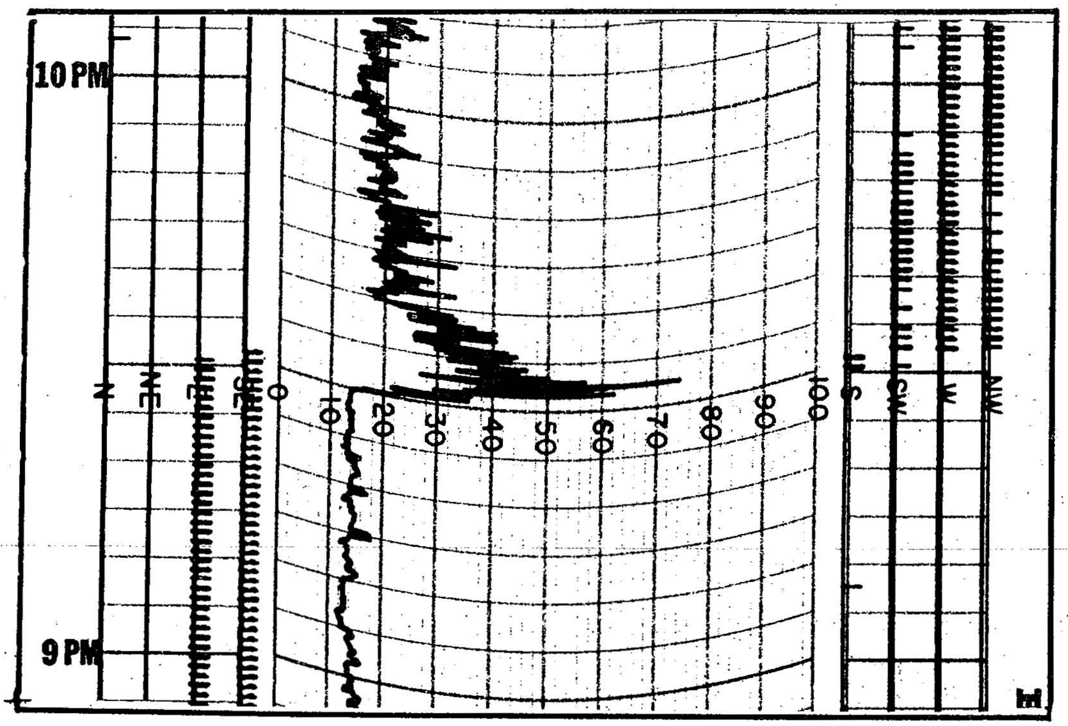


Figure 2.- Wind record for station 27, 2100-2200 CST, June 7, 1962. Wind speed is in knots.

Rainfall is recorded continuously by a weighing-type rain gage. The chart drum of the instrument is geared to make one revolution in 24 hours. The charts are changed only after significant rainfall, and several days of null record are often contained on one chart. A sample rain gage chart and a microbarogram for May 3, 1961 are shown in figure 3. One may note that rain began near the time of the pressure rise and that the bulk of the rain fell during the first 15 minutes.

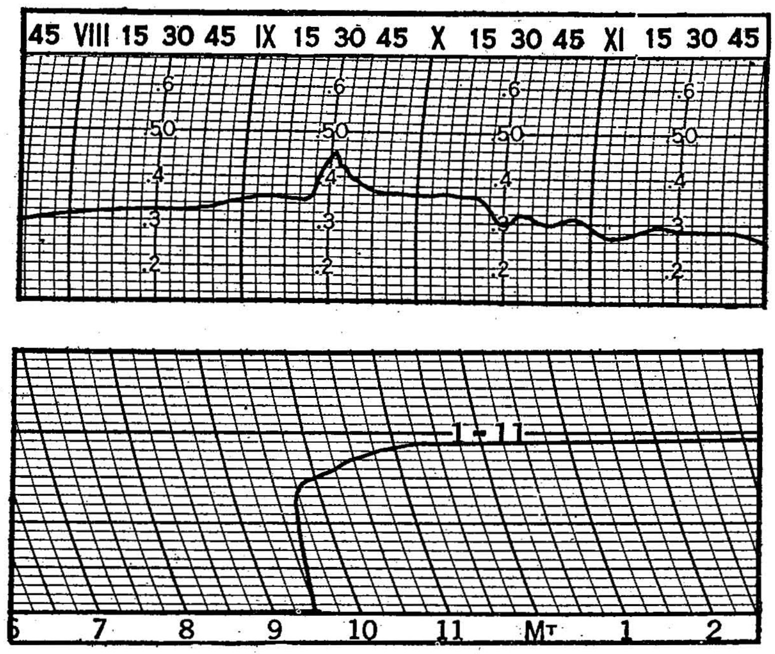


Figure 3.- Microbarogram trace, 2000-2300 CST, and rain gage trace, 1900-0100 CST, May 3-4, 1961, for station 12.

Time of the charts is indicated with respect to "on" and "off" by the cooperative observers who service the instruments. Allowing for some inaccuracies in the observers' timepieces and slight play in the gearing systems of the instrument clocks, timing accuracy to less than 5 minutes cannot be assured. One exception is the wind recorder record. These charts are changed by Weather Bureau technicians, and the accuracy is generally to 1 minute.

During a portion of the 1962 season and all of the 1963 season a timing system was in operation by which the instrument pens at each station were jogged twice daily. The system was actuated by the wind recorder, whose timing was fairly accurate. The pen jogs permit times to be corrected. Consistent time is obtained for all instruments at each station, but consistency from one station to the next is not completely assured. Preliminary use of these data indicate that they are much superior to those in which the timing is based on the observers' settings.

3. INSTRUMENT MALFUNCTIONS

The occasional malfunction of an instrument may impair its record. Many malfunctions are obvious; e.g., no trace is produced. A few are not so apparent. These should be determined before the reduction and analysis begin.

Each chart should be examined critically and a log made listing those records which cannot be used or which can be used only in a certain way. Past records indicate that there may be a few rather subtle but serious malfunctions that persist for an entire season. The detection of such malfunctions is an art and requires both a knowledge of meteorology and instrumentation. Such was the case with respect to the barograph at station 13. Pressure changes were recorded, and the traces appeared valid. However, in the synoptic analyses of sea level pressure, values at station 13 were too low when the pressure was high and too high when the pressure was low. Apparently a defect in the instrument did not provide a proper expansion of the trace. The record was still usable with respect to the character and time of pressure change, but it could not be used in quantitative analyses.

In general, a malfunction may be suspected when a series of analyses shows a persistent singularity at any one station. In some instances the singularity may be removed by applying an empirical correction. One must be sure, of course, that the singularity is not real.

4. TIME AND SKEW CORRECTIONS

The time of a chart may be in error. The time must be corrected before the data are used. Gross errors become apparent when an isochrone analysis of characteristic changes is made, but the errors should be corrected before this point is reached.

As a first approach, the stated "on" and "off" times should be checked to note any that fail to agree with the times that the trace began and ended. In some instances the stated times may be in error; in others the trace times may be in error. Errors of this sort are typically 15, 30, or 60 minutes, and result from the observer's inadvertently setting the instrument pen on the wrong time line. The errors can be resolved, usually, by referring to the "on" and "off" times of charts for the preceding and the following days.

Charts on which the pen jogging system was used may be corrected by noting the time of the pen jog on the charts.

Time gained or lost by instrument clocks should be corrected, also, with the gain or loss distributed linearly for the period of the chart.

Occasionally, a chart may be placed in a skewed position on the drum, with one end not seated against the flange. This malalignment results in a progressive displacement of the trace from the seated end to the unseated end. The "skew" error can be determined by comparing the traces at the breakover margins of the chart. The differences thus noted are then used as additive corrections, being distributed linearly from the full value at the elevated end of the chart to zero at the seated end.

In rare instances, neither end of the chart may be seated against the flange. This may be the case when chart readings appear consistently too low. The amount of the chart displacement can be determined by comparing "on" and "off" values of the traces with those of the preceding and the following days, assuming these charts to have been seated properly. The differences noted are then used as additive corrections.

The errors from a malalignment of the charts are generally small. They seldom exceed 0.02 in. Hg on the barogram or 2.0° F. on the thermogram. However, they are sufficiently large to require correction.

Time and skew corrections for the barograms of June 7, 1962 are shown in table 1.

5. ANALYSIS OF CHANGE LINES

The traces of most instruments are generally smooth and slowly changing due to the expanded time scales of the charts. Superimposed on these slow changes may be comparatively abrupt changes or discontinuities, which are called *characteristic changes*. Some characteristic changes may be noted in the traces shown in figures 1 and 2.

When a characteristic change occurs, in turn, at several adjacent stations of the network, it may be inferred that the change is organized along a line, which is the *change line*. Characteristic changes, constituting change lines, are shown in figures 4, 15, and 20.

A portion of the characteristic change must be selected as a *reference*. Typical references are the beginning and the ending of the change. For a positive change the beginning of the rise is chosen, and for a negative change the ending of the fall is usually chosen. Thus, *rise lines* represent the leading edges of rising fields, and *fall lines* represent the troughs of falling fields.

Rise lines are related to the various elements, as follows: (1) Pressure --- the leading edge of a High, (2) Temperature --- a warm front, (3) Relative humidity --- the leading edge of higher humidities, (4) Wind speed --- the leading edge of a gust line, and (5) Rainfall --- the leading edge of the rainfall.

Fall lines are related to the various elements, as follows: (1) Pressure --- a pressure trough, and (2) Relative humidity --- the trough of lowest humidity. In the case of temperature the beginning of the fall is used as the reference, and this line corresponds to a cold front.

In cases where pressure and relative humidity rise immediately following falls there is then a coincident line of fall and rise. The relative amounts of the fall and rise are compared to determine whether the line is classed as a rise line or a fall line.

With respect to wind direction the reference is the direction shift. In most instances this closely approximates the leading edge of the gust line.

The progress of change lines may be shown by an *isochrone-amplitude analysis*. This is constructed by plotting the reference time of the change and the amount of the change for each station. Isochrones, i.e., lines of equal time, are drawn to show successive locations of the change line. Amplitude lines, i.e., lines of equal amounts of change, are also drawn. In the case of multiple changes and changes that are superimposed on other changes, extreme care must be exercised to assure that the same change is followed. This may require a critical comparison of the traces at adjacent stations and the construction of tentative isochrone charts to ascertain whether or not continuity is maintained. Isochrone-amplitude analyses of a pressure rise, a peak wind gust, a temperature rise, and a humidity fall are shown in figures 5, 8, 16, and 21. Isochrones are shown only at 15-minute intervals. In practice, they are constructed at 5-minute intervals.

The construction of isochrone-amplitude charts is an aid in determining time errors, as previously noted. The charts also show the extent, the intensities, and the motions of the change lines. Finally, they provide the best means for the positioning of discontinuities with respect to synoptic analyses.

Change lines are so numerous in most case studies that a means of identification is required. The following categories have been devised: "R" and "F" -- pressure rise and pressure fall; "W" and "C" -- temperature rise and temperature fall; and "M" and "D" -- relative humidity rise and relative humidity fall. Change lines of each type are then numbered serially in the order of their appearance over the network from some beginning time; e.g., "R1," "R2," "R3," etc.

On the synoptic analyses, pressure rise and humidity rise lines are shown as heavy solid lines. Pressure fall and humidity fall lines are shown as heavy dashed lines. Temperature rise and temperature fall lines are shown by conventional warm and cold front symbols. Further identification is provided by an encircled letter and number. The positions of the change lines are copied from the isochrone analyses.

6. READING THE DATA

At the present time the charts are read manually, and values are hand tabulated. However, mechanical trace readers can be used to digitalize the data and to apply corrections to them.

Data are read to the nearest minute when obtaining reference times for an isochrone-amplitude analysis. Data for synoptic charts are read, generally, at 5-minute intervals, except that rainfall is read only at 15-minute intervals. The readings are copied in alternate columns of a tabulation sheet, the blank columns being retained for the entry of corrected values. Two or three columns at the right of the sheet are used for listing the corrections to be applied.

Values are read to 0.005 in. Hg for pressure, 0.5° F. for temperature, 1 percent for relative humidity, 16 points of the compass for wind direction, and 1 kt. for wind speed. Precipitation amounts are read to 0.02 in.

Care must be exercised in making readings for any traces that require time corrections. It is helpful to have a tabulation of the time corrections in view, so that corrections may be applied as the traces are read.

Care must be exercised, also, in selecting the proper trace to read. Because of the 12-hour revolution of the barogram and hygrothermogram, there will always be two traces in a 24-hour period. There will be more, if the chart has been left on for more than one day. In many instances the proper trace is obvious, but when it is not, it should be followed to the time on or off to ascertain whether it is with respect to a.m. or p.m. In some instances, the traces may be entwined or superimposed, and considerable ingenuity is required to select the proper one. A final decision may even have to await a preliminary synoptic analysis of the data.

7. PRESSURE

Values of pressure are most meaningful when reduced to a sea level representation. Unfortunately, conventional methods of reduction are not satisfactory for small-scale data. The barographs record station pressure, but their settings may not be precise, and the settings may even drift over a period of time. Precise elevations of the stations may not be known. Finally, small errors in the reduction, which are tolerable in large-scale analyses, may produce disturbing singularities in small-scale analyses.

Fujita [2] has devised a method in which pressure is given as either an excess or a deficit with respect to some reference value. This method is useful with respect to simple pressure changes, but there is a problem in determining a reference value when a multiplicity of pressure changes is involved.

The method to be described was first used in 1948 to represent the pressure field with respect to data from the small-scale network of the U.S. Weather Bureau's Cloud Physics Project [3]. It is not dependent upon an assumed reference value, and it has a further advantage in that it incorporates, also, the values of the larger scale pressure field.

In the method a synoptic time is chosen when pressure over the network is fairly uniform and slowly changing. Preferably, this time is within a day or two of the time to be studied. Altimeter settings at regular hourly reporting stations within and surrounding the network are plotted for the selected time, and isobars are drawn for each 0.01 in. Hg. Equivalent sea level pressure values, i.e., altimeter setting values, are then determined by interpolation for individual network stations from the isobaric analysis. These values are then compared with the barogram readings for the same time, and the differences are used as additive corrections for the times of interest. As a check, a second synoptic time can be chosen and the process repeated. The two sets of corrections obtained are then averaged.

Altimeter settings are used rather than computed sea level pressures, since the latter contain an adjustment for the average temperature during the preceding 12 hours. The smoothing inherent in this adjustment is unwanted in small-scale analyses.

An example of the method is presented for the evening of June 7, 1962. During this time, numerous pressure changes occurred over the network. Reproductions of the barograph traces with respect to pressure rise line R4 are shown in figure 4, and the isochrone-amplitude analysis of R4 is shown in figure 5. The case is of interest, since damaging winds, and possibly a tornado, occurred in the vicinity of station 27 upon the passage of R4. One may note in figure 4 that the pressure rise at station 27 was interrupted by a sharp pressure fall, believed to have been the tornado low.

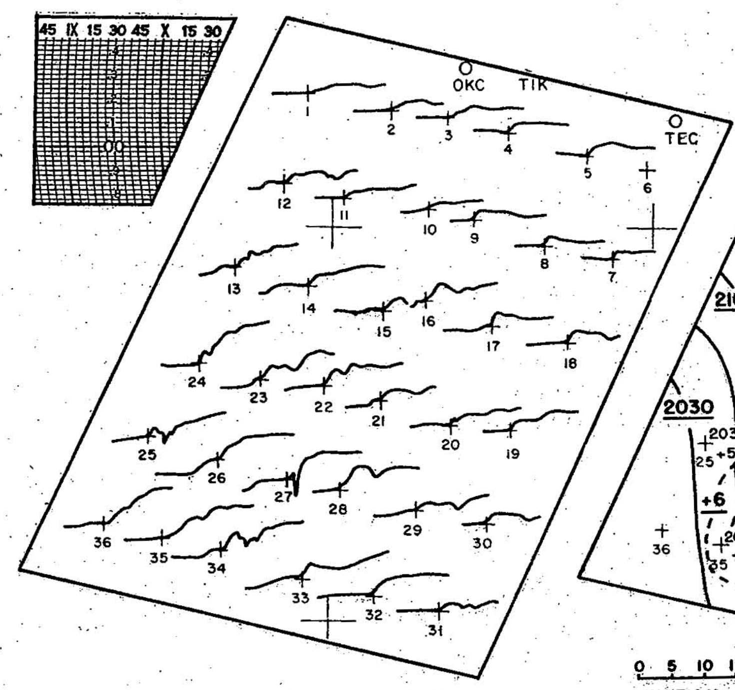


Figure 4.– Traces of pressure rise line R4, 2030-2330 CST, June 7, 1962. Other pressure changes were present also. The beginning of R4 is located on the station cross.

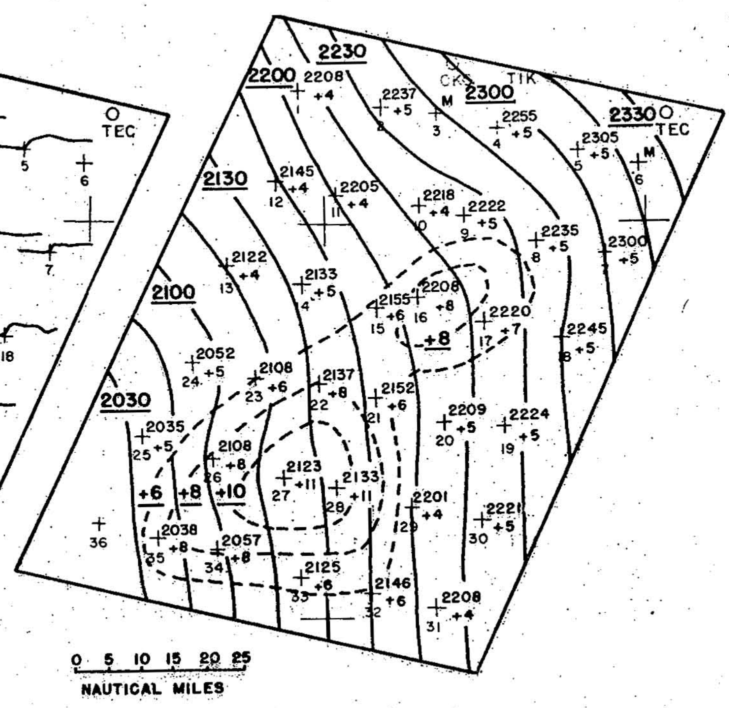


Figure 5.– Isochrone-amplitude analysis of pressure rise line R4, 2030-2330 CST, June 7, 1962. The isochrones are drawn as solid lines at 15-minute intervals and are labeled in Central Standard Time. Isopleths of the amplitude are drawn as dashed lines at 0.02 in. Hg intervals, beginning with 0.06 in. Hg.

Sea level pressure corrections were obtained from the altimeter setting analyses for 1800 CST, June 7, and for 0600 CST, June 8, using values at OKC (Oklahoma City), HBR (Hobart), SPS (Wichita Falls), and ADM (Ardmore). The altimeter setting analysis and the interpolated values for the 36 Beta network stations and the surrounding Alpha network stations for 1800 CST, June 7, are shown in figure 6.

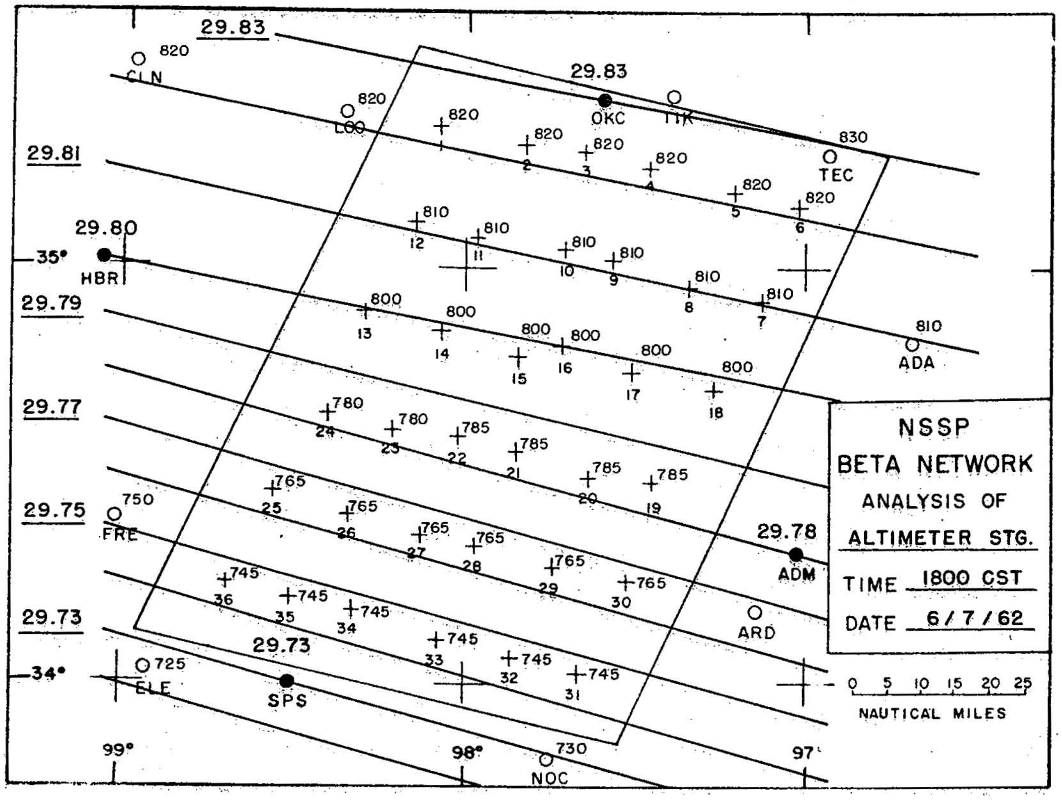


Figure 6.– Altimeter setting analysis for 1800 CST, June 7, 1962. The analysis was made as a linear interpolation with respect to the reported values at OKC (Oklahoma City), HBR (Hobart), SPS (Wichita Falls), and ADM (Ardmore). The interpolated values for the Beta stations and the surrounding Alpha stations are plotted.

When the corrections prepared from the altimeter setting analyses are applied to a series of charts, it is found that the values at a few stations may be slightly low or slightly high. This probably results from small deviations between the actual pressure field and the field interpolated from the altimeter setting analyses. These deviations are reduced, but not eliminated completely, by averaging. They are corrected empirically by adding or subtracting the small amount required to improve their fit.

The tabulated corrections for 1800 CST, June 7, for 0600 CST, June 8, and their averages, are shown in table 1. Also shown are the small empirical corrections, the skew corrections, and the total corrections. Empirical corrections were made at only nine stations, and only one of these exceeded 0.01 in. Hg. The entire correction for station 28 was empirically determined, since its trace was not usable at the times of the altimeter setting analyses.

The isobaric analysis for 2145 CST is shown in figure 7. This chart has been selected from a series prepared at 5-minute intervals for the period, 1930-2355 CST. The major pressure rise line, R4, and a small advance pressure rise line, R7, are indicated. Some lesser pressure change lines that were present to the rear of R4 have been omitted for simplicity. The meso-Highs to the rear of the pressure rise lines, and the gradients on their leading edges, are well shown. There is a reasonable fit to the superimposed radar echo, shown at an attenuation of 21 db.

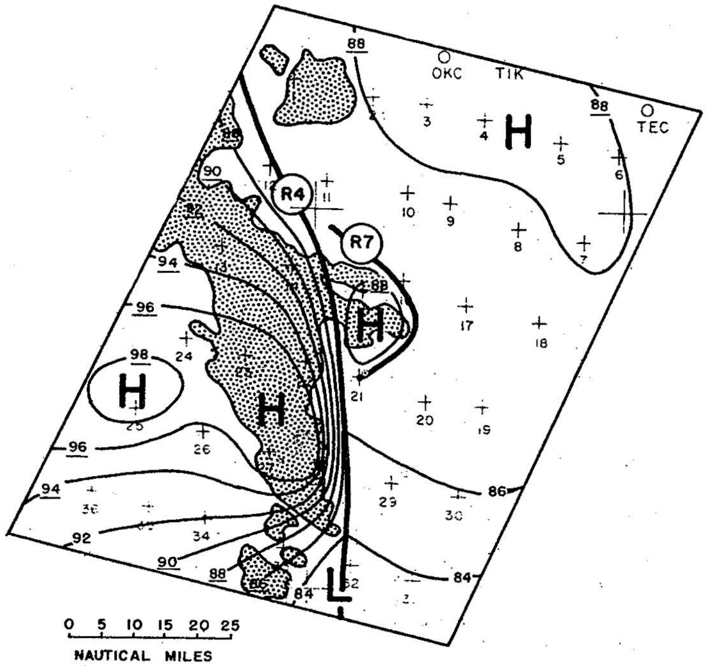


Figure 7.- Sea level pressure analysis, 2145 CST, June 7, 1962. Isobars are drawn at 0.02 in. Hg intervals with high and low centers indicated. Pressure rise lines R4 and R7 are shown as heavy solid lines. Radar echoes at an attenuation of 21 db. are stippled.

8. WIND

There have been serious deficiencies in the wind data gathered by the NSSP Beta network. Much of the data gathered in 1961 was worthless due to chronic malfunctions of the wind recorders. Data gathered in 1962 were much better, although corrections must be applied to much of it. Wind direction heads were not oriented properly early in the season, and data gathered prior to the period, May 11-16, 1962, require corrections for wind direction. These corrections have been noted on the original charts.

Wind direction is recorded on eight channels. Since two adjacent channels may record at the same time, the direction is shown to 16 points of the compass. In cases of buffeting, the direction may be recorded on 3 adjacent channels. For those instances in which the direction is consistently in one channel or consistently in two channels, the value may be taken as indicated; e.g., a continuous record in the south channel would be read as "south" or 180°. A continuous record in both the south and southeast channels would be read as "south-southeast" or approximately 158°. A continuous record in the south channel with occasional record in the southeast channel should be weighted toward the south, with a direction of perhaps 165°.

Table 1. Barogram correction for June 7-8, 1962.

Sta	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	0	0.000	0.820	0.260	0.560	0.910	0.325	0.585	0.570	0.000	0.570
2	0	0.000	0.820	0.180	0.640	0.905	0.255	0.650	0.645	0.000	0.645
3	?	0.020	0.820	-----	-----	0.905	-----	-----	-----	-----	-----
4	0	0.000	0.820	0.260	0.560	0.900	0.330	0.570	0.565	0.000	0.565
5	0	0.000	0.820	0.315	0.505	0.900	0.385	0.515	0.510	0.000	0.510
6	M	M	0.820	-----	-----	0.895	-----	-----	-----	-----	-----
7	0	0.000	0.810	0.320	0.490	0.885	0.385	0.500	0.495	+0.010	0.505
8	+60	0.020	0.810	0.280	0.530	0.890	0.340	0.550	0.560	−0.010	0.550
9	M	M	0.810	-----	-----	0.890	-----	-----	-----	-----	-----
10	0	0.000	0.810	0.265	0.545	0.895	0.320	0.575	0.560	0.000	0.560
11	0	0.000	0.810	0.320	0.490	0.895	0.415	0.480	0.485	0.000	0.485
12	0	0.000	0.810	0.205	0.605	0.900	0.300	0.600	0.600	0.000	0.600
13	M	M	0.800	-----	-----	0.890	-----	-----	-----	-----	-----
14	0	0.010	0.800	0.250	0.550	0.885	0.325	0.560	0.565	0.000	0.565
15	0	0.020	0.800	0.125	0.675	0.880	0.205	0.675	0.695	−0.010	0.685
16	+5	0.000	0.800	0.220	0.580	0.880	0.295	0.585	0.580	+0.010	0.590
17	0	0.000	0.800	0.340	0.460	0.880	0.410	0.470	0.465	0.000	0.465
18	0	0.000	0.800	0.295	0.505	0.875	0.360	0.515	0.510	0.000	0.510
19	0	0.000	0.785	0.165	0.620	0.865	0.240	0.625	0.620	0.000	0.620
20	0	0.000	0.785	0.280	0.505	0.865	0.360	0.505	0.505	0.000	0.505
21	0	0.000	0.785	0.230	0.555	0.870	0.315	0.565	0.560	0.000	0.565
22	+5	0.020	0.785	0.145	0.640	0.870	0.235	0.635	0.660	−0.010	0.650
23	0	0.010	0.780	0.110	0.670	0.875	0.205	0.670	0.680	−0.010	0.670
24	0	0.000	0.780	0.220	0.560	0.875	0.320	0.555	0.560	0.000	0.560
25	0	0.000	0.765	0.240	0.525	0.865	0.335	0.530	0.530	0.000	0.530
26	0	0.000	0.765	0.145	0.620	0.865	0.265	0.600	0.610	+0.010	0.620
27	0	0.020	0.765	0.230	0.535	0.860	0.320	0.540	0.560	−0.010	0.550
28	0	0.000	0.765	-----	-----	0.860	-----	-----	-----	+0.590	0.590
29	0	0.000	0.765	0.405	0.360	0.855	-----	-----	0.360	+0.020	0.380
30	0	0.000	0.765	0.115	0.650	0.855	0.190	0.665	0.660	0.000	0.660
31	0	0.000	0.745	0.240	0.505	0.840	0.290	0.550	0.520	0.000	0.520
32	0	0.000	0.745	0.185	0.560	0.845	0.270	0.575	0.570	0.000	0.570
33	−60	0.010	0.745	0.350	0.395	0.845	0.450	0.395	0.405	−0.010	0.395
34	−15	0.000	0.745	0.160	0.585	0.850	0.245	0.605	0.595	0.000	0.595
35	0	0.000	0.745	0.180	0.565	0.850	-----	-----	0.565	0.000	0.565
36	0	0.000	0.745	0.210	0.535	0.855	0.325	0.530	0.530	0.000	0.530

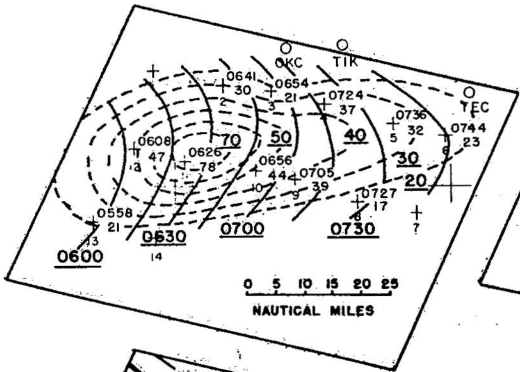
(1) Time correction in min.
(2) Skew correction in in.
(3) Altimeter setting, 1800 CST, June 7
(4) Barogram reading, 1800 CST. June 7
(5) Barogram correction, 1800 CST, June 10
(6) Altimeter setting, 0600 CST, June 8
(7) Barogram reading, 0600 CST, June 8
(8) Barogram correction, 0600 CST, June 8
(9) Average of (5) and (8) plus (2)
(10) Empirical correction
(11) Final correction, (9) plus (10)

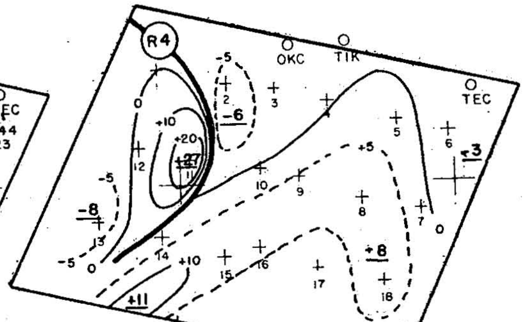
In some instances a channel may fail to record. This may not be obvious immediately, since channels on either side will receive some of the record. An error is introduced if the wind direction is taken to be what is recorded. Channels that malfunction should be ascertained before the reading begins. This can be ascertained by examining the charts for periods when a shift in wind occurs through the direction involved. In some instances the record can still be used by subjectively inferring the direction from the adjacent channels.

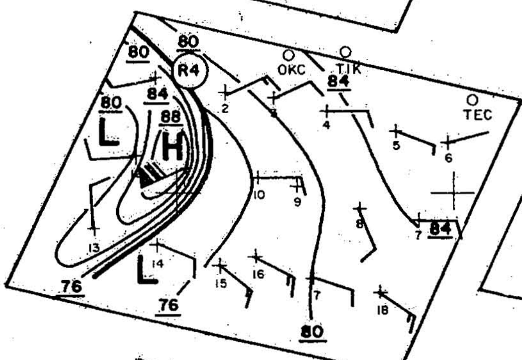
Characteristic changes in the wind can be shown by an isochrone-amplitude analysis. One such analysis is the time and amount of the peak gust. An isochrone-amplitude analysis of a peak gust which occurred over the northern portion of the network from 0558-0744 CST, April 10, 1962, is shown in figure 8. A maximum gust of 78 kt. was recorded at station 11 (Chickasha) at 0626 CST. Damage occurred in the vicinity of Chickasha, and residents reported the storm as a tornado.

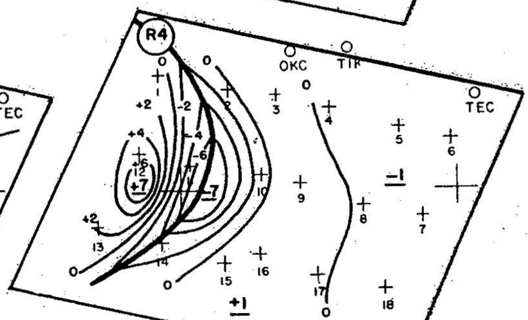
Winds may be plotted on a synoptic chart in the conventional manner. Such a plot is shown for 0625 CST, April 10, 1962, in figure 9. The sea level pressure analysis has been simplified to show only the major pressure rise line, R4. The pattern of flow with respect to pressure can be noted.

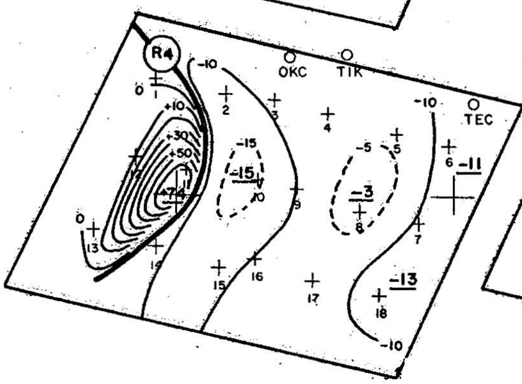
Derived properties of the wind field may be related to the fields of pressure, rainfall, temperature, and relative humidity. Such relationships have been shown for systems observed by the U.S. Weather Bureau's Cloud Physics Project network [4]. The derived kinematic properties are computed by forming various sums of the horizontal space derivatives of the wind. One method of doing this is to decompose the winds into their <u>u</u>- and <u>v</u>-components and, from isotach analyses of these, to measure the horizontal space derivatives. The <u>u</u>- and <u>v</u>-components were obtained for 0625 CST, April 10, 1962, and analyses of these are shown in figures 10 and 11. The isotachs have been adjusted to conform to the pressure rise line R4, which is also indicated. From these analyses, horizontal velocity divergence and the vertical component of relative vorticity were computed for selected points, using a 10-n.mi. measuring interval. This is the smallest interval that can properly be used with the Beta network data; the interval should not be appreciably smaller than the spacing between stations. The divergence analysis is shown in figure 12. The pressure rise line lay in a zone of convergence (negative values) with the most intense convergence near station 11. A corridor of positive divergence was present in advance of the line, and an intense center of positive divergence was present to the rear of the line. The vorticity analysis is shown in figure 13. The pressure rise line lay in a zone of approximately zero vorticity but with an intense center of cyclonic (positive) vorticity southwest of station 11 and an intense center of anticyclonic (negative) vorticity near station 14. The intense cyclonic vorticity southwest of station 11 appears to have been related to the tornado that was reported in this area.











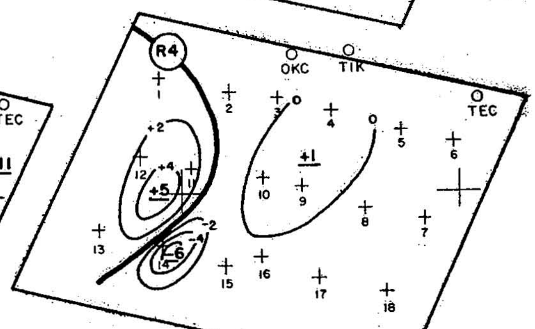


Figure 8. (Upper)- Isochrone-amplitude analysis of peak wind gust, 0600-0745 CST, April 10, 1962. Isochrones are drawn as solid lines at 15-minute intervals and are labeled in Central Standard Time. Isopleths of the amplitude, i.e., the value of the peak gust, are drawn as dashed lines at 10-kt. intervals, beginning with 20 kt.

Figure 9. (Middle)- Sea level pressure analysis with plotted winds, 0625 CST, April 10, 1962. Isobars are drawn at 0.04 in. Hg intervals with high and low centers indicated. The major pressure rise line, R4, is shown as a heavy solid line. Winds are plotted with a barb equal to 10 kt. and a pennant equal to 50 kt.

Figure 10. (Lower)- Analysis of the u-component of wind, 0625 CST, April 10, 1962. Isotachs are drawn as solid lines at 10-kt. intervals. Dashed lines are used where a 5-kt. interval is warranted. The position of the pressure rise line is indicated, also.

Figure 11. (Upper)- Analysis of the v-component of the wind, 0625 CST, April 10, 1962.

Figure 12. (Middle)- Analysis of horizontal velocity divergence, 0625 CST, April 10, 1962. Isopleths are drawn for each 2 $hr.^{-1}$, and centers are labeled. The position of the pressure rise line is indicated.

Figure 13. (Lower)- Analysis of the vertical component of relative vorticity, 0625 CST, April 10, 1962. Isopleths are drawn for each 2 $hr.^{-1}$, and centers are labeled. The position of the pressure rise line is indicated.

9. RAINFALL

Characteristic changes in rainfall, i.e., beginnings and endings of rainfall and the inclusive amounts, may be indicated by an isochrone-amplitude analysis. The reference time may be taken as the time that rainfall begins, or the time of a marked increase in the rate of rainfall. The amplitude is then taken as the amount of rain occurring during the period that follows.

Rainfall may be analyzed also with respect to fixed time intervals, and such analyses may be related to other parameters, such as pressure and radar echoes. A time interval of 15 or 30 minutes has been found most satisfactory. Difficulties in reading the compressed time scale of the 24 hour rain gage chart preclude the use of an interval smaller than 15 minutes. It is hoped that this difficulty can be alleviated in the 1964 and future seasons by the use of 12 hour gears on the rain gages.

A rainfall analysis for the period 2100-2130 CST, May 3, 1961, is shown in figure 14. The positions of three pressure rise lines at 2130 CST have been added, and the area featured by radar echoes during the 30-minute period is outlined. The isohyets have been constructed to agree with isochrone-amplitude analyses (not shown) of three separate precipitation lines, which corresponded to the three pressure rise lines. One may note that the rainfall was wholly contained in the area of radar echoes, and that separate maxima in the amounts of rainfall were present to the rear of the three pressure rise lines.

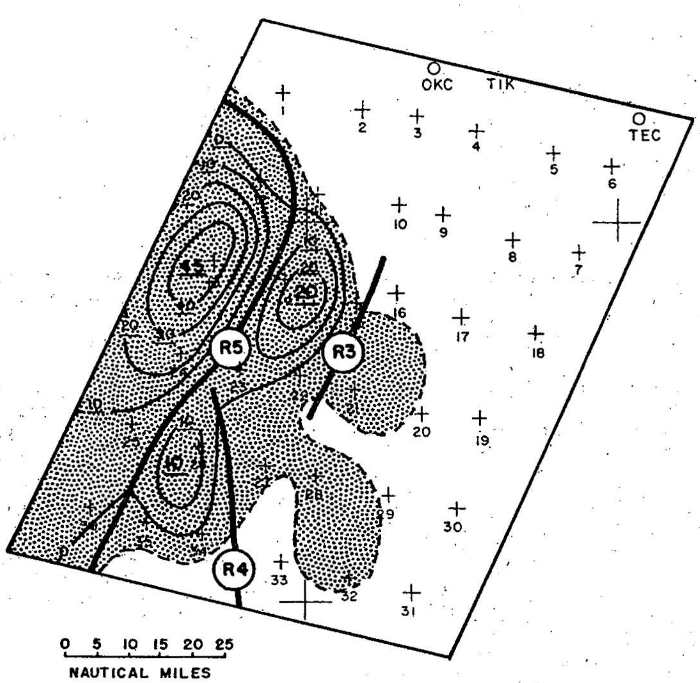


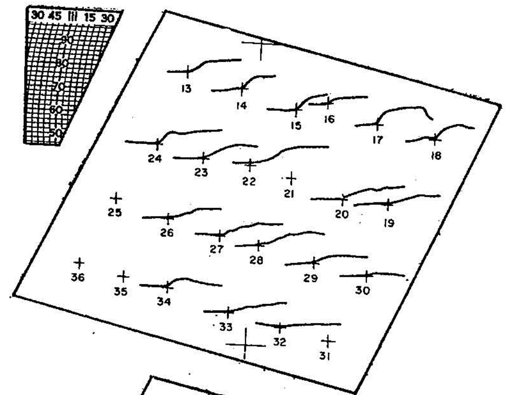
Figure 14.- Analysis of 30-minute rainfall amounts, 2100-2130 CST, May 3, 1961. Isohyets are drawn as solid lines for 0.10 in. (30 min.)$^{-1}$ intervals. The positions of three pressure rise lines are indicated by the heavy solid lines. The area covered by radar echoes during the period, 2100-2130 CST, is stippled.

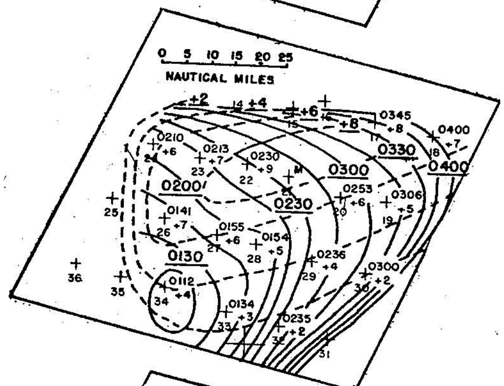
10. TEMPERATURE

Characteristic temperature changes may be noted and isochrone-amplitude analyses prepared in the manner described previously. A characteristic temperature rise that occurred over portions of the network from 0112-0400 CST, May 4, 1961, is shown in figure 15. An isochrone-amplitude analysis of the temperature rise is shown in figure 16. The temperature rise was generated at a point near station 34, as indicated by the circular isochrone. Features of this case are contained in another report [5].

Ideally, temperatures should be read from the thermograms, and the values should be used without correction. Unfortunately, there may be errors in the settings of the instruments, and unless these are corrected, the resulting analyses may contain spurious gradients of temperature.[2] The errors become apparent when a series of charts is analyzed and it is found that certain stations are singularly too low or too high. An analysis of raw values of temperature for 0600 CST, May 5, 1961, is shown in figure 18. This was a time when storm systems were not passing the network, and one would expect that temperature conditions would be fairly uniform. The colder temperatures at stations 9, 16, and 21 appear too low, and the temperature of 58° at the Alpha network station, ELE (Electra) appears much too low.

As a first approach, a time is selected when it is reasonable to assume that temperatures over the network are fairly uniform and slowly changing. Temperatures are plotted for this time, and a very smoothed analysis is made. Differences





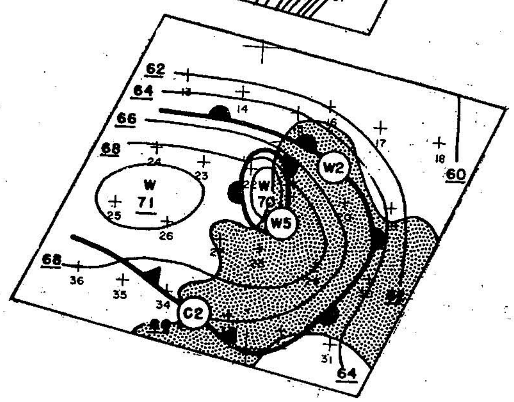


Figure 15. (Upper)- Traces of temperature rise line W2, 0115-0400 CST, May 4, 1961. The beginning of the rise is located on the station cross. Traces are not shown for stations 1-12, 25, 31, 35, and 36, since the temperature rise line did not pass these stations.

Figure 16. (Middle)- Isochrone-amplitude analysis of temperature rise line W2, 0115-0400 CST, May 4, 1961. The isochrones are drawn as solid lines at 15-minute intervals and are labeled in Central Standard Time. Isopleths of the amplitude are drawn as dashed lines at 2° F. intervals, beginning with 2° F.

Figure 17. (Lower)- Analysis of corrected temperatures, 0300 CST, May 4, 1961. Isotherms are drawn as solid lines at 2° F. intervals. The positions of temperature rise line W2 and a newly generated rise line, W5, are shown by warm front symbols. The retreating portion of W2 is shown as a temperature fall line, C2. The position of the radar echo is shown as a stippled area.

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[2] The Beta network thermographs were adjusted better during the 1963 season than previously. Only a few empirical corrections are required in the use of the 1963 temperature data.

between recorded values and those interpolated from the smoothed analysis are then used as tentative corrections. A smoothed analysis for 0600 CST, May 5, 1961, is shown in figure 19. Interpolated values have been plotted. Both the raw and interpolated values are given in table 2, together with the tentative corrections. The tentative corrections did not exceed 3° F.; however, one may note that the corrections of -2° F. at station 20 and of +3° F. at station 21 would have made a net difference of 5° F. (10 n. mi.)$^{-1}$ in the gradient of temperature between the stations.

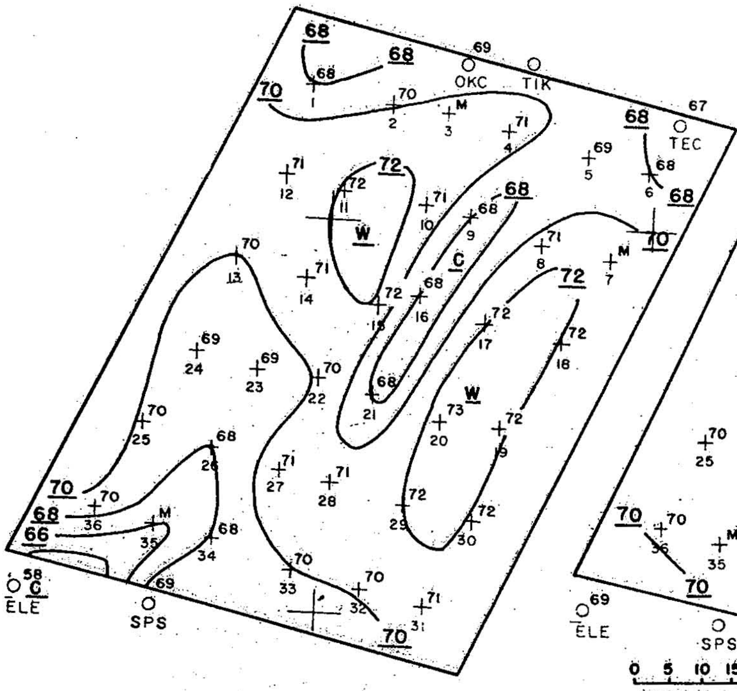


Figure 18.- Analysis of uncorrected temperatures, 0600 CST, May 5, 1961. Isotherms are drawn at 2°F. intervals.

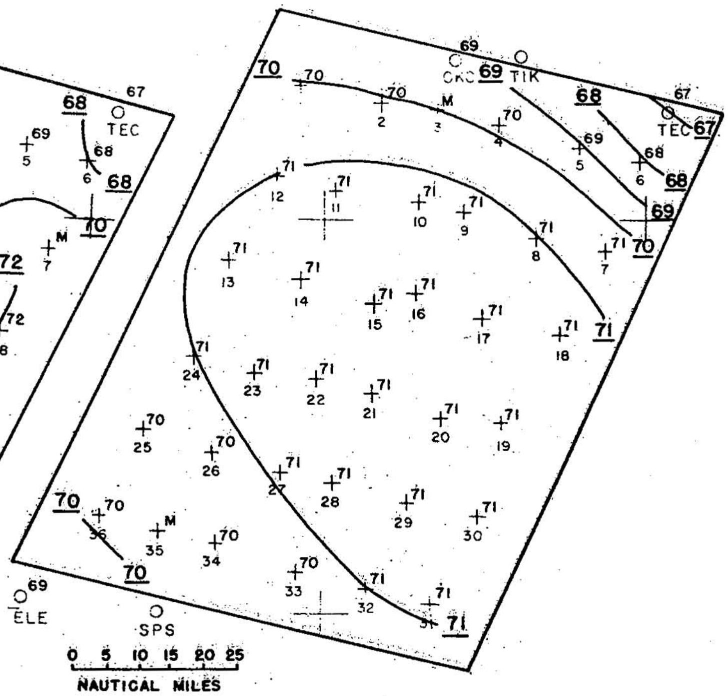


Figure 19.- Smoothed temperature analysis, 0600 CST, May 5, 1961. Isotherms are drawn at 1°F. intervals. Values interpolated to the nearest whole degree are plotted.

When the tentative corrections are employed on a series of charts, it is found that some values are still too low or too high. This is inevitable, since the smoothed analysis from which the corrections were made would not be a perfect fit. Empirical corrections must now be made to provide values that are consistent for every analysis in the series. The empirical corrections determined are listed in table 2. They are about as large as the tentative corrections. In this case they were determined with respect to a series of temperature analyses that were made at 5-minute intervals for the period, 1900 CST, May 3, to 1100 CST, May 4. The final corrections are shown in table 2. They were sometimes rather large, ranging from -4.0° F. to +5.5° F.

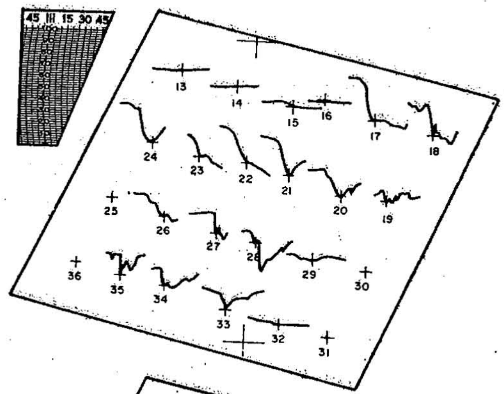
An analysis of corrected temperatures for 0300 CST, May 4, 1961, is shown in figure 17. The position of temperature rise line W2 is shown, as well as a newly generated rise line, W5. The location of the radar echo is shown, and one may note that the warmer air was present to the rear of the echo.

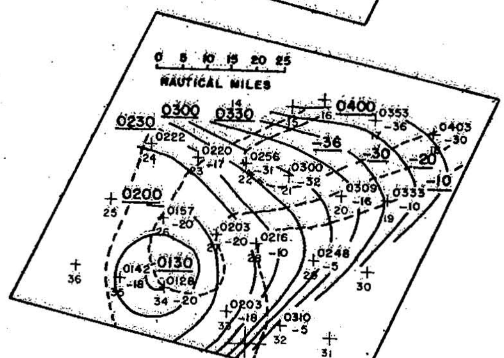
II. RELATIVE HUMIDITY

Characteristic changes in relative humidity may be noted and isochrone-amplitude analyses prepared. A humidity fall that occurred over portions of the network from 0128-0400 CST, May 4, 1961, is shown in figure 20. An isochrone-amplitude analysis of the humidity fall is shown in figure 21. The humidity fall was generated at a point near station 24 and occurred in association with the temperature rise shown in figures 15 and 16.

Extreme accuracy is not claimed for the hygrograph. Nevertheless, some corrections can be made to improve the accuracy. Some of the errors result from a maladjustment of the instrument, and these can be noted. A typical maladjustment is one in which the pen is permitted to trace above 100 percent. In other cases it may be restrained from ever reaching 100 percent. A correction that is crude, although helpful, is made by examining many traces and noting the values recorded during periods when near saturation may be assumed. The recorded values are then compared with an assumed 100 percent value, and the differences are used as corrections. Differences of less than 5 percent are ignored, and corrections are made in multiples of 5 percent. The corrections determined for May 4, 1961 are shown in table 2. The corrections ranged from -10 to +10 percent.

An analysis of corrected relative humidities is shown in figure 22. The positions of humidity fall line D2 and a humidity rise line, M2, and the radar echo, are indicated. One may note the presence of the drier air to the rear of the echo.





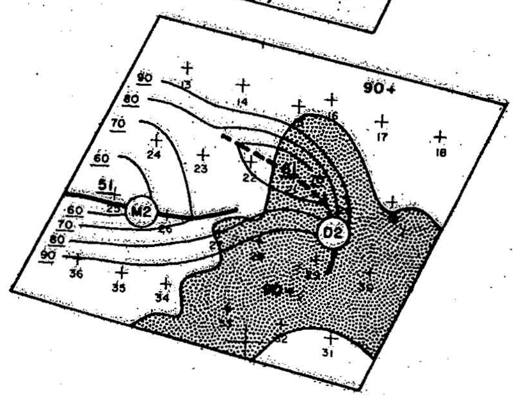


Figure 20. (Upper)- Traces of relative humidity fall line D2, 0130-0400 CST, May 4, 1961. The ending of the fall is located on the station cross. Traces are not shown for stations 1-12, 25, 30, 31, and 36, since the humidity fall line did not pass these stations.

Figure 21. (Middle)- Isochrone-amplitude analysis of humidity fall line D2, 0130-0400 CST, May 4, 1961. The isochrones are drawn as solid lines at 15-minute intervals and are labeled in Central Standard Time. Isopleths of amplitude are drawn as dashed lines at 10 percent intervals, beginning with 10 percent.

Figure 22. (Lower)- Analysis of corrected relative humidity, 0300 CST, May 4, 1961. Isopleths are drawn as solid lines at 10 percent intervals. The positions of humidity fall lines D2 and humidity rise line M2 are indicated by heavy dashed and heavy solid lines, respectively. The position of the radar echo is shown as a stippled area.

Table 2. Thermogram and hygrogram corrections for May 3-5, 1961. Time and skew corrections are not shown.

Sta	(1)	(2)	(3)	(4)	(5)	(6)
1	68	70	+2	+1.5	+3.5	0
2	70	70	0	0.0	0.0	0
3	M	70	M	+5.0	+5.0	M
4	71	70	-1	+1.0	0.0	M
5	69	69	0	+1.0	+1.0	M
6	68	68	0	0.0	0.0	0
7	M	71	M	+1.5	+1.5	0
8	71	71	0	-0.5	-0.5	0
9	68	71	+3	+1.0	+4.0	0
10	71	71	0	+1.5	+1.5	+5
11	72	71	-1	+0.5	-0.5	+10
12	71	71	0	0.0	0.0	-5
13	70	71	+1	-0.5	+0.5	+5
14	71	71	0	+1.0	+1.0	0
15	72	71	-1	+0.5	-0.5	+5
16	68	71	+3	+2.5	+5.5	0
17	72	71	-1	+1.5	+0.5	0
18	72	71	-1	+0.5	-0.5	0
19	72	71	-1	+1.0	0.0	-5
20	73	71	-2	+0.5	-1.5	0
21	68	71	+3	M	M	-5
22	70	71	+1	0.0	+1.0	0
23	69	71	+2	-1.5	+0.5	+10
24	69	71	+2	-0.5	+1.5	0
25	70	70	0	0.0	0.0	-10
26	68	70	+2	-1.5	+0.5	0
27	71	71	0	0.0	0.0	-5
28	71	71	0	+1.0	+1.0	0
29	72	71	-1	+2.0	+1.0	+5
30	72	71	-1	+1.0	0.0	0
31	71	71	0	+0.5	+0.5	0
32	70	71	+1	-2.0	-1.0	-5
33	70	70	0	0.0	0.0	0
34	68	70	+2	+2.0	+4.0	+5
35	M	70	M	-4.0	-4.0	+5
36	70	70	0	-1.0	-1.0	0

(1) Recorded temperatures, 0600 CST, May 5, 1961
(2) Assumed temperatures from smoothed analysis, 0600 CST, May 5, 1961
(3) Tentative corrections to temperature
(4) Empirical corrections to temperature
(5) Final temperature corrections for May 3-5, 1961
(6) Relative humidity corrections for May 3-5, 1961

12. RADAR

The plotting of radar echoes from PPI scope photographs is helpful in determining the significance of the various analyses. Echoes should be traced as precisely as possible, and the times selected should not vary by more than a minute from the times of the chart. Insofar as possible, the echoes should be obtained from the same radar set, and the same values of attenuation and antenna tilt should be selected for all charts in the series. In most instances, those echoes should be selected in which a fair amount of attenuation was employed. Otherwise, the portions of the echo that are best related to the analyses may be covered up.

Radar echoes have been added to the analyses in figures 7, 14, 17, and 22. They were obtained from scope photographs of the WSR-57 at Will Rogers Field, Oklahoma City. In figure 7, a photograph at an attenuation of 21 db. was used. This was selected from the several degrees of attenuation available as having the best fit to the pressure analysis. In figure 14, there was no choice of attenuation; some attenuation was used, and this was estimated at 12 db. The same was true for the radar echo shown in figures 17 and 22, where the attenuation was estimated at only 6 db.

As step-gain programs improve, one may expect a better presentation of radar with respect to small-scale surface analyses. One may care to show contoured echoes, and in some cases isopleths of reflectivity may be related.

13. CONSISTENCY CHECKS AND SUPPORTING ANALYSES

In a case study, the various analyses of pressure, wind, rainfall, temperature, and humidity should be compared. Some of the parameters can be expected to show certain relationships to other parameters. Where a logical relationship is not shown, the data and the analyses should be examined again to make sure they are correct. Care must be taken, however, that analyses are not biased in favor of a pre-selected hypothesis. In general, the analysis of one parameter should be made independently of the analyses of the others. Any necessary adjustments should be made when they are compared. In some instances, an apparent inconsistency may be a useful finding, which tells something about the processes involved. These should be exploited.

Small-scale studies are enhanced when they are related to the larger-scale environment in which they are embedded. Large-scale surface and upper air charts should be analyzed as background information. Individual soundings are helpful to extend the findings at the surface vertically. In some instances, sounding observations, such as the serial soundings at 90-minute intervals, can be planned ahead of time to give this support. In other instances, the researcher must depend on regular soundings. Occasionally, a regular sounding will show more by accident than a series of planned soundings. Regular soundings should be examined for these rare finds. In the case of May 4, 1961, an early sounding at Ardmore, Okla., revealed a deep layer of warm, dry air aloft, which was related to the warm, dry air shown at the surface in figures 19 and 22.

14. SUMMARY

Small-scale surface network observations provide an abundance of data for research. The capability of the network to record continuously assures that all occurrences at network stations will be documented. The data are sufficient, generally, to provide many examples of particular features.

Extensive corrections may be required in the reduction of the surface network data. These have been described. Special techniques of analysis are used and some of these have been presented.

15. ACKNOWLEDGMENTS

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